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(54) **Method of manufacturing a leaf of a leaf spring.**

(57) A method of preparing a leaf of a leaf spring involves a heating step in which a raw material of a leaf spring is heated to austenite range temperature, a rolling step in which the above heated material is formed to a desirable shape, a working step in which the above rolling material is cut to a fixed length and/or to form a clip hole and/or a bolt hole or the like, and a cooling step in which a curvature is imposed on the above working material so that it cools to harden as curved.

Other modified methods are also described in which the working step is carried out in two or three stages with suitable intermediate reheating before final cooling.

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METHOD OF MANUFACTURING A LEAF OF A LEAF SPRING

This invention relates to a method of manufacturing a leaf of a leaf spring, i.e. laminated spring for cars or other vehicles.

There is currently a requirement for light laminated springs since cars or other vehicles are themselves lighter in weight. If however only the weight is decreased without change in spring quantity, the durability of the leaf spring decreases, and permanent set increases in proportion to the weight decrease. Thus, when making lighter springs the durability and the resistance to permanent set are typically secured by increasing the maximum stress and concomitantly the hardness decreases the antitearing and the antishock quantities. Tearing occurs by collision with flying small stones or the like. It shortens the life of the leaf spring and satisfactory characteristics are not obtained with such hardness.

Accordingly, it is known to provide a heat treatment called "ausforming" or "modified ausforming" on a leaf spring component, to avoid defects. "Ausforming" is a heat treatment wherein the raw material is subjected to hardening in a hot bath at 300° to 600°C, then heated at a temperature in the austenite range and then subjected to rolling work at constant temperature thereby obtaining a fine martensite structure on quenching by quenching; while "modified ausforming" means a heat treatment wherein the raw material is subjected to rolling after being heated to austenite range temperature, and to oil hardening soon after the rolling work to obtain the fine martensite structure. By these heat treatments is obtained a leaf spring leaf of good antitearing and shock characteristics. However, since in the heat treatment quench hardening is performed soon after rolling, the raw material becomes of high hardness, which makes such works as forming an eye portion or a hole for a clip, a bolt hole or the like impossible or very difficult sufficiently to decrease the overall productivity.

Thus, to position an axle or for installing a bolt to fix a plurality of laminated springs or to form a rivet hole for securing a clip can only be done by a drill. However, even with a drill cutting is very difficult since the hardness of the material to be cut is so high. It is impossible to form a bolt hole or the like by plastic working.

Accordingly, neither ausforming nor modified ausforming is satisfactory as a method of preparing the leaf spring.

This invention sets out to provide a method of preparing a leaf spring leaf which makes it possible to ensure the durability and low permanent fatigue set in spite of lighter overall weight. It also sets out to provide a leaf spring leaf of good anti-tearing and antishocking qualities in high productivity.

The invention consists in a method of manufacturing a leaf of a leaf spring which comprises the successive steps of (a) maintaining a suitable length of ferrous metal at a temperature in the austenitic range (b) rolling the length of metal to a desired shape and size such that a leaf spring leaf can be cut therefrom and (c) cooling the leaf to harden it while held in such curvature as required for its subsequent assembly; characterised in that between the rolling step and the cooling and hardening step there is interposed at least one working step chosen from: cutting the desired length of the rolled leaf; forming at least one bolt hole; forming at least one clip hole; bending one or both end regions of a leaf to facilitate subsequent rolling of an attachment eye; and rolling of said attachment eye.

In one form of the invention the working step consists of cutting the rolled material to a desired length to form a spring leaf and forming in the said length at least one bolt hole and/or at least one clip hole.

In a second form of the invention the working step consists of cutting the rolled material to a desired length to form a spring leaf; forming in the said length at least one bolt hole and/or at least one clip hole; bending at least one end portion of the said leaf to facilitate rolling of an attachment eye; and thereafter rolling said attachment eye.

In a third form of the invention the working step consists of cutting the rolled material to a desired length to form a spring leaf: forming in the said length at least one bolt-hole and/or at least one clip hole; and reheating the worked material to a temperature within a stable austenitic range.

In a fourth form of the invention the working step consists of cutting the rolled material to a desired length to form a spring leaf; forming in the said length at least one bolt hole and/or at least one clip hole; bending at least one end portion of the said leaf to facilitate rolling of an attachment eye; reheating the worked material to a temperature within a stable austenitic range; and rolling said attachment eye.

In a fifth form of the invention the working step consists of cutting the rolled material to a desired length to form a spring leaf; forming in the said length at least one bolt hole and/or at least one clip hole; reheating the worked material to a temperature within a stable austenitic range; bending at least one end portion of said leaf to facilitate rolling of an attachment eye; rolling said attachment eye; and again reheating the worked material to a temperature within a stable austenitic range.

In a sixth form of the invention the working step consists of cutting the rolled material to a desired length to form a spring leaf; forming in the said length at least one bolt hole and/or at least one clip hole; bending at least one end portion of the said leaf to facilitate rolling of an attachment eye; reheating the worked material to a temperature within a stable austenitic range; rolling said attachment eye; and again reheating the worked material to a temperature within a stable austenitic range.

Cooling may be effected by oil tempering from a temperature above 730 ° C or water tempering from a temperature above 680 ° C. Preferably the temperature of the leaf is above 730 ° C prior to any repeating stage. Initial heating is preferably 900 ° C±25 ° C. Reheating is preferably 850 ° C±25 ° C. Rolling is preferably effected at 850 ° C±25 ° C and at 10-60% rolling reduction. Preferably a stress peening treatment is effected at 120 to 180 kg/mm^2 of initial stress when the leaf is cooled to a temperature of 400 ° C ± 10 ° C during tempering.

The invention will be further described with reference to the accompanying drawings in which:

Fig. 1(A) and (B) are graphs which illustrate the influences of the heating temperatures in the heating steps of this invention;

Fig 2 (A) and (B) are graphs which illustrate the influences of the rolling reduction in the rolling step and of the cooling times after rolling;

Fig. 3 is a graph which shows relations between cooling times and temperatures in the cooling step of this invention; and

Fig. 4 is a graph which shows relations between the tempering temperatures and life of the leaf spring, and between the initial stresses and life of the leaf spring.

First, a preferred form of the first and second forms of the invention will be explained.

Steel materials such as spring steel, stainless steel and the like are used as raw materials for a leaf spring. Modified SUP-10 steels of improved hardenability and increased the amount of component added in SUP-10 or SUP are desirable. The heating temperature in the heating step is held at an austenite range temperature: a desirable temperature is 900 ° C±25 ° C. When the heating temperature of 925 ° C is held form more than 10 minutes as shown in Fig. 1 (A) and (B), the growth of grain size of the material suddenly accelerates so that fine grains are not obtained, if the heating is performed for not more than five minutes at 875 ° C, the removal of segregation and inner strain of the material and the formation of the solid solution of the components are insufficient whereby the fatigue strength of the eventual leaf spring is decreased.

The surface of the heated material in the heating step is covered with adherent oxide scale. This may be removed with a water jet descaler.

Rolling in two directions is then performed to a desired shape. The temperatures of the material at this time are most preferably 870 ° C±25 ° C in breadth rolling and 850 ° C±25 ° C in plate thickness rolling respectively. Further, the roll reduction in the plate thickness is pereferably 10 to 60%. If rolling reduction in the plate thickness is (as shown in Fig. 2 (A) and (B)) out of the range 10 to 60% or if the treatment temperature is less than 825 ° C, the fatigue strength of the eventual leaf spring will be less. If such rolling effected at more than 875 ° C, the grain size of the material rapidly increases.

Further, in the working step, the working is performed according to the various kinds of leaf spring leaf needed for the final product. Some leaves do not need formation of any eye portion or holes and for these only cutting to a fixed length is performed. this step is done before the hardening step when the hardness of the material is low.

In the next cooling step, oil hardening or water hardening is performed in a state where the leaf is held at the desred curvature and soon after the practice of the above steps. If an aging hardening alloy having a good hardenability is used, air cooling may be used. In this cooling step, for oil hardening, the leaf goes through a hardening process shown by the S-curve in Fig. 3. In Fig. 3, a solid line 1 shows a hardening process of the invention, while broken line 2 shows a cooling process wherein a material is once cooled by air to room temperature after rolling, heated up to the austenite range temperature again, then cooled to 700 ° C by air and subjected to oil hardening. The drawing shows that the air-cooled material, of line 2, after reheating can be sufficiently martensitic even on oil quenching after air cooling at 700 ° C. However, in this invention as shown by line 1 since the nose of the S-curve shifts to the left (broken line solid line), a sufficiently martensitic structure can not be obtained unless the oil quenching is performed from above 730 ° C. Accordingly, in the practice of the present invention, it is preferable to perform the hardening before the material temperature cools below 730 ° C. With water hardening, a sufficient hardening effect can be obtained from above 680 ° C since the cooling rate of the water hardening is faster than that of the oil hardening.

The hardness of the material increases by such hardening process and fine martensite structure is obtained. Such fine martensite structure shows a high toughness which contributes the increase of antitearing and antishock qualities. After the hardening step, the final product may be made by performing a shot peening or a stress peening treatment in order to give compressive remaining stress on the surface through tempering. At this time, the tempering temperature is desirable to be 400±10 ° C, and the initial stress of the stress peening is preferably to be 120-180 Kg/mm². This is because the tempering temperature has a peak at near 400 ° C with 120 to 180 Kg/mm² of initial stress as shown in Fig. 4. The optimum conditions for longest life are obtained at 400 ° C and 140 Kg/mm² of initial stress.

Preferred forms of the third and fourth forms of the invention will be described as follows.

The first heating step and rolling step are respectively the same as that of the first and second forms described above. In the working step after the rolling step, working procedures according to the kind of leaf for the eventual leaf springs are the same as those of the first and second invention. In the third form of the invention such working as cutting the rolling material to a fixed length and forming a securing hole for a clip, a bolt hole and the like, and in the fourth form of the invention such working as bending work for facilitating subsequent rolling of an eye portion, and rolling thereof, as well as the above working steps are also performed.

The second heating step is a reheating step wherein the air-cooled material is reheated to a stable austenite range temperature. This reheating is preferably performed before the material temperature becomes less than 730 ° C. This is because if the material which has cooled to become less than 730 ° C is reheated, it takes a long time to return to the austenite phase, ferrite and pearlite are decomposed thereby and fine martensite structure cannot be obtained by hardening. A preferable reheating temperature in this step is 850 ° C±25 ° C and the time over 825 ° C should preferably be less than 1 minute.

The next cooling step is the same as the cooling step in the first and the second from of the invention. However, in the fourth form the eye portion is formed just before the cooling step. The formation of this eye portion is then easy since it is performed before hardening.

In subsequent steps, the shot peening or stress peening can be performed as in the first and second forms of the inventions.

Preferred fifth and sixth forms of the invention will be described as follows.

The first heating step, rolling step and working step are the same as the first heating step, rolling step and working step (i.e. the first working step) in the third and the fourth forms of the invention respectively.

In the next second heating step, re-heating is performed in the same conditions as in the second reheating step of the third and fourth inventions. The air cooled material is reheated to a stable austenite range temperature.

Then, an eye portion, or suitable bending, is formed in a second working step, said working being easy because it is prior to cooling. In this case, bending means a state wherein the leaf is bent to a desired shape in accordance with the final spring requirements. Although the material is cooled in the second working step, the material is again re-heated in the same conditions as the re-heating step above, in a further re-heating step in order again to re-heat the air cooled material to a stable austenite range temperature.

The next cooling step is the same as the cooling step in the first and second inventions. The material is esstentailly subjected to the same treatment as in the first and second inventions, but in steps after the cooling step.

Prior to the final cooling step and while working is still easy, the leaf spring material is worked to make an eye portion, a hole for a clip or a bolt hole.

The grain size is fined by rolling the heating material in a rolling step.

In the cooling step, the fine grain sizes maintained through the previous steps are fixed to a fine martensite structure thereby increasing the hardness of the final leaf spring material.

The reheating stages are performed to make it possible both to obtain a normal martensite structure in the cooling step and to readily work the material.

In the product leaf spring, the old austenite crystal grains lessen to JIS#10 to #12, while the antitearing and the antishocking increase.

Example

A laminated leaf spring of 8^t x 70^b x 1150^e x 7^p in dimension having eye portions for securing at both ends is prepared according to the following steps in order and conditions by using the material SUP - 10.

Example 1

(1) heating step:

A leaf spring material is heated to 900° ± 25° C. After the temperature of the material reaches 875° C, it is kept for 5 - 10 minutes. After taking out the heated material from the furnace, oxide scale adhered to the surface is removed. Then it is conveyed to the next step.

(2) rolling step:

The material is rolled in a breadth direction at 870° C ± 25° C of the material temperature and rolled in a plate thickness direction at 850° C ± 25° C under a roll reduction of 15%.

(3) working step:

Eye portions are formed at both ends of #1 leaf using a conventional eye rolling machine. Further, #2 leaf to #7 leaf are cut the top end thereof respectively.

(4) cooling step:

The material fed from the prior step is secured to desired curvature and subjected to oil hardening. The material temperature is 730° C to 800° C.

Thereafter, the tempering is performed at 400° C ± 10° C while the material is subjected to stress peening at 140 Kg/mm^2 of initial stress.

Example 2

(1) first heating step:

The same condition as Example 1 - (1).

(2) Rolling step:

The same condition as Example 1 - (2).

(3) Working step:

The top end portion of #1 leaf is subjected to top bending working for forming eye rolling. The leaves of #2 to #7 are cut at the extreme ends thereof respectively. The material temperature after working is 735° C to 770° C.

(4) A second heating step:

The material from the prior step is repeated by being put into a heating furnace to achieve a temperature of 850° C + 25° C, i.e. heated for about one minute after temperature of the material reaches 825° C.

(5) Cooling step:

The #1 leaf is formed with eye portions at both ends thereof using a conventional eye rolling machine and then oil hardening is performed at the secured desired curvature. Further, #2 leaf to #7 leaf is subjected to oil hardening, with the desired curvature secured after cooling. The material temperature at this time is 730° C to 800° C.

The steps after cooling step are the same as in Example 1.

Example 3

(1) A first heating step:

the same conditions as Example 1 - (1)

(2) Rolling step:

the same conditions as Example 1 - (2)

(3) First working step:

the same conditions as Example 2 - (3)

(4) Second heating step (reheating): the same conditions as Example 2 - (4)

(5) Second working step:

Eye portions are formed at both ends of the material using a conventional rolling machine. The material temperature after working is 750° C.

(6) Third heating step (reheating): the same conditions as the above second heating (i.e. reheating) step

(7) Cooling step:

the same conditions as Example 1 - (4)

Thereafter, #1 leaf is subjected to the same treatment as in Example 1 - (4).

#2 leaf to #7 leaf treated as in Example 2, made from the component described in Example 1, 2 and 3.

Comparison tests of leaf springs against conventional leaf springs, performed at the same conditions, are shown in Table 1. The numerals in table 1 indicate repetitions undergone until the leaf spring breaks.

Table 1

samples	life (repetition)
Example 1 product	1,338,600
Example 2 product	1,235,297
Example 3 product	1,210,247
conventional product 1	181,957
conventional product 2	142,721
conventional product 3	157,629

Thus the products of the present invention shows a marked improvement.

The products according to this invention which show a weight decrease of 40% as compared with the conventional products.

As samples, (8 to 13.5^{t})x 70^{b} x 1150^{1} x 2^{p} of dimension and 8^{t} x 70^{b} x 1150^{1} x 7^{p} of dimension are used both this product and the conventional product respectively. The results are shown in Table 2.

Table 2

sample	life (repetition)
Product of Example 1	321,259
Product of Example 2	386,732
Product of Example 3	417,253
conventional product 1	181,957
conventional product 2	142,721
conventional product 3	157,629

From Table 2 it can be seen that even if the weight of this product decreases by 40% a longer life than the conventional product is obtained.

Thus, a leaf spring having excellent antisettling, antitearing and antishocking properties and an extended life can be obtained. It is possible to make the weight lighter yet still obtain a prolonged life.

Further, since various working stages such as formation of eye portions, or punching a hole for clip or bolt holes are performed on the material before hardening, the productivity is increased.

Claims

1. A method of manufacturing a leaf of a leaf spring which comprises the successive steps of (a) maintaining a suitable length of ferrous metal at a temperature in the austenitic range (b) rolling the length of metal to a desired shape and size such that a leaf spring leaf can be cut therefrom and (c) cooling the leaf to harden it while held in such curvature as required for its subsequent assembly; characterised in that between the rolling step and the cooling and hardening step there is interposed at least one working step chosen from: cutting the desired length of the rolled leaf; forming at least one bolt hole; forming at least one clip hole; bending one or both end regions of a leaf to facilitate subsequent rolling of an attachment eye; and rolling of said attachment eye.

2. A method as claimed in claim 1, characterised in that the working step consists of cutting the rolled material to a desired length to form a spring leaf and forming in the said length at least one bolt hole and/or at least one clip hole.

3. A method as claimed in claim 1, characterised in that the working step consists of cutting the rolled material to a desired length to form a spring leaf; forming in the said length at least one bolt hole and/or at least one clip hole; bending at least one end portion of the said leaf to facilitate rolling of an attachment eye; and thereafter rolling laid attachment eye.

4. A method as claimed in claim 1 characterised in that the working step consists of cutting the rolled

material to a desired length to form a spring leaf; forming in the said length at least one bolt-hole and/or at least one clip hole; and reheating the worked material to a temperature within a stable austenitic range.

5. A method as claimed in claim 1, characterised in that the working step consists of cutting the rolled material to a desired length to form a spring leaf; forming in the said length at least one bolt hole and/or at least one clip hole; bending at least one end portion of the said leaf to facilitate rolling of an attachment eye; reheating the worked material to a temperature within a stable austenitic range; and rolling said attachment eye.

6. A method as claimed in claim 1, characterised in that the working step consists of cutting the rolled material to a desired length to form a spring leaf; forming in the said length at least one bolt hole and/or at least one clip hole; reheating the worked material to a temperature within a stable austenitic range; bending at least one end portion of said leaf to facilitate rolling of an attachment eye; rolling said attachment eye; and again reheating the worked material to a temperature within a stable austenitic range.

7. A method as claimed in claim 1, characterised in that the working step consists of cutting the rolled material to a desired length to form a spring leaf; forming in the said length at least one bolt hole and/or at least one clip hole; bending at least one end portion of the said leaf to facilitate rolling of an attachment eye; reheating the worked material to a temperature within a stable austenitic range; rolling said attachment eye; and again reheating the worked material to a temperature within a stable austenitic range.

8. A method as claimed in any one preceding claim characterised in that cooling is effected by oil tempering from a temperature above 730° C.

9. A method as claimed in any one of claims 1 to 7 characterised in that cooling is effected by water tempering from a temperature above 680° C.

10. A method as claimed in any one preceding claim characterised in that the temperature of the leaf is above 730° C prior to any reheating stage.

11. A method as claimed in any one preceding claim characterised in that the initial heating stage is maintained at 900° C ± 25° C.

12. A method as claimed in any one preceding claim characterised in that the temperature attained in any reheating stage is 850° C ± 25° C.

13. A method as claimed in any one preceding claim characterised in that rolling is effected at 850° C ± 25° C and at a 10-60% rolling reduction.

14. A method as claimed in any one preceding claim, characterised in that a stress peening treatment is effected at 120 to 180 kg/mm^2 of initial stress when the leaf is cooled to a temperature of 400° C ± 10° C during tempering.

FIG. 1 (A)

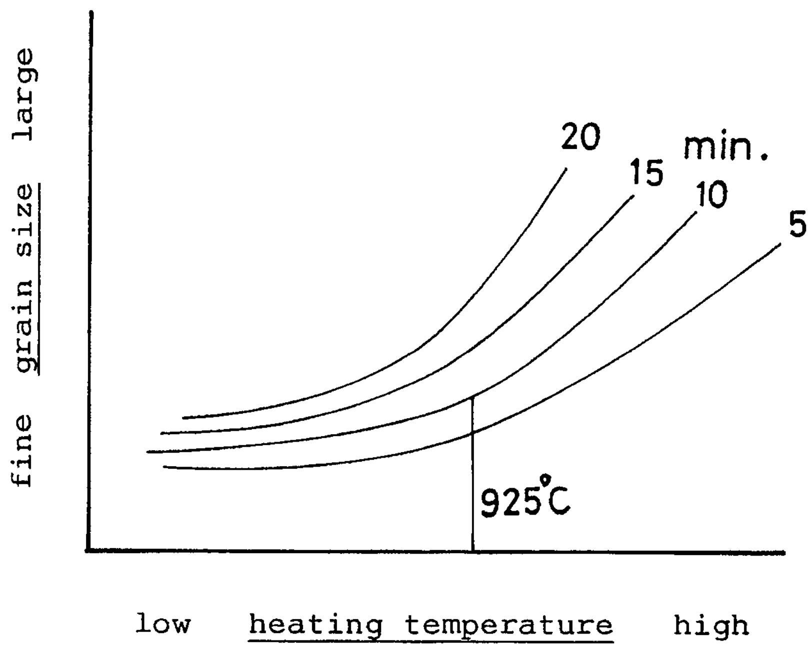

fine grain size large
20
15
min.
10
5
925°C
low heating temperature high

FIG. 1 (B)

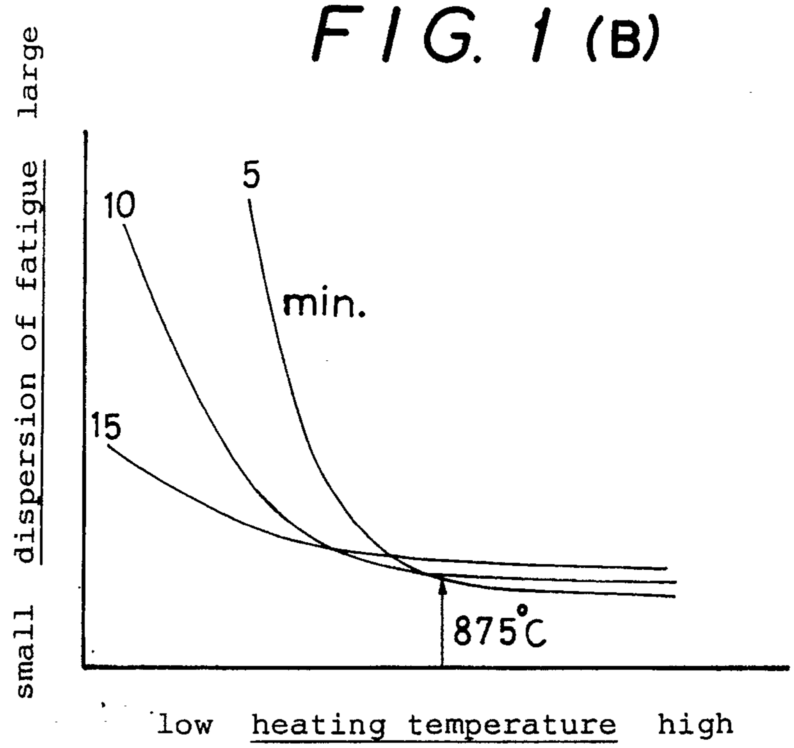

small dispersion of fatigue large
10
5
min.
15
875°C
low heating temperature high

FIG. 2 (A)

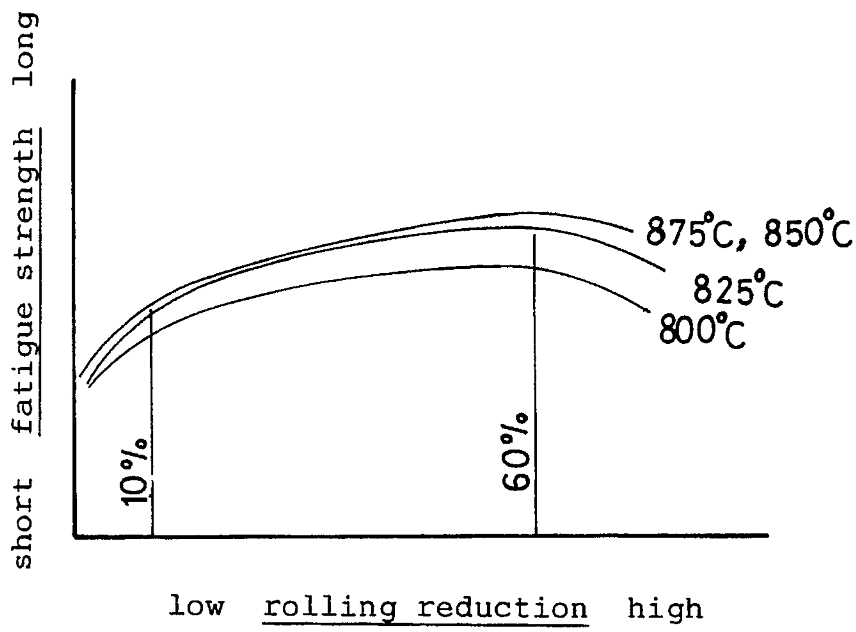

short fatigue strength long
875°C, 850°C
825°C
800°C
10%
60%
low rolling reduction high

FIG. 2 (B)

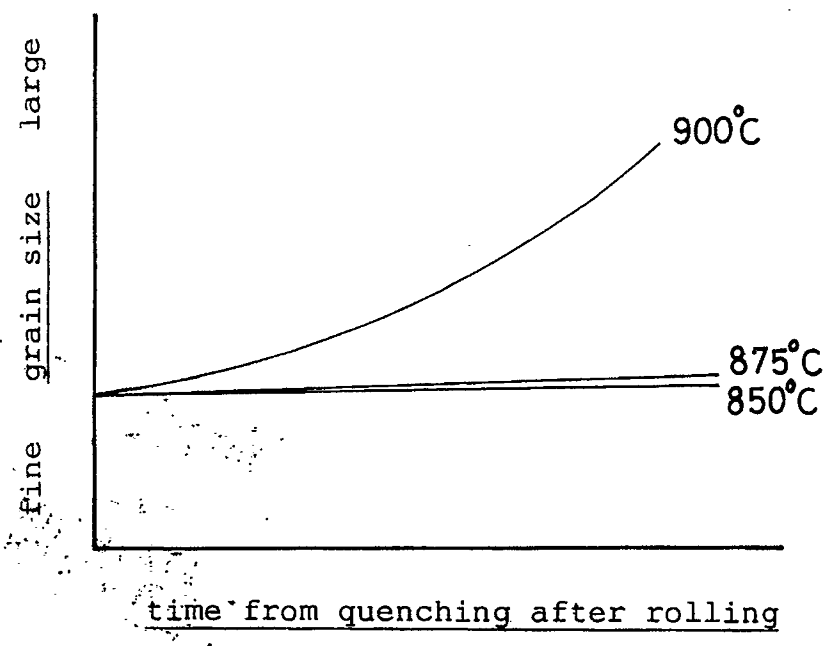

fine grain size large
900°C
875°C
850°C
time from quenching after rolling

FIG. 3

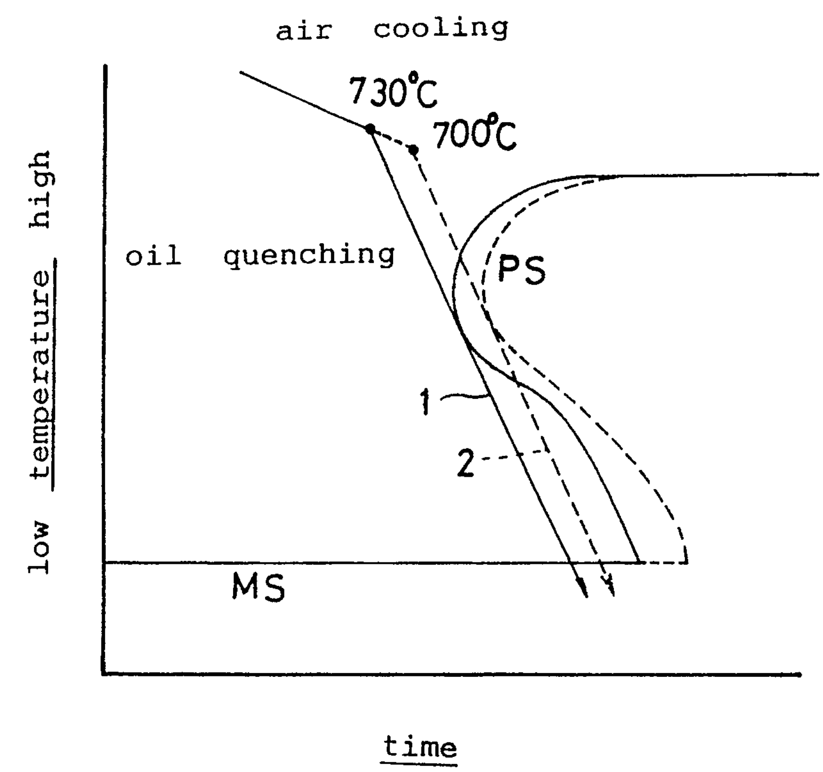
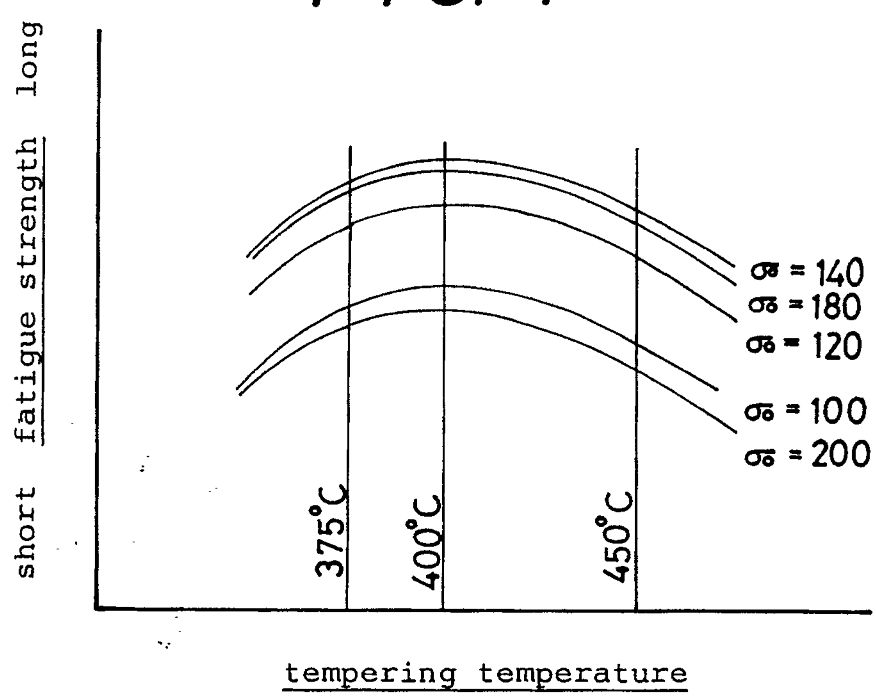

air cooling
730°C
700°C
high
temperature
low
oil quenching
PS
1
2
MS
time

FIG. 4


long
fatigue strength
short
σB = 140
σB = 180
σB = 120
σB = 100
σB = 200
375°C
400°C
450°C
tempering temperature

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 31 2679

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US-A-3 345 727 (R.S. KOMARNITSKY) * Claims; column 6, lines 40-57 *	1,9-12	C 21 D 9/02 B 21 D 53/88
X	US-A-2 145 989 (W.J. MERTEN) * Claims; page 1 - page 1, left-hand column *	1	
X	NL-A-7 316 770 (J.C. VERHOEVEN) * Claims *	1	
A	GB-A- 362 340 (W. WILLIAMSON et al.)		
A	GB-A-1 053 960 (STAHLWERKE BRUNINGHAUS)		
A	GB-A-1 114 520 (FORD)		
A	FR-A-2 018 018 (FORD)		
A	MACHINERY, vol. 96, 6th January 1960, pages 15-21; "Leaf spring manufacture"		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

C 21 D
B 21 D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13-08-1990	MOLLET G.H.J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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